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Laser Absorption spectrometer instrument for tomographic 2D-measurement of climate gas emission from soils

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One of the most intricate effects in climate modelling is the role of permafrost thawing during the global warming process. Soil that has formerly never totally lost its ice cover now emits climate gases due to melting processes[1]. For a better prediction of climate development and possible feedback mechanisms, insights into physical procedures (like e.g. gas emission from underground reservoirs) are required[2]. Therefore, a long-term quantification of greenhouse gas concentrations (and further on fluxes) is necessary and the related structures that are responsible for emission need to be identified. In particular the spatial heterogeneity of soils caused by soil internal structures (e.g. soil composition changes or surface cracks) or by surface modifications (e.g. by plant growth) generate considerable complexities and difficulties for local measurements, for example with soil chambers. For such situations, which often cannot be avoided, a spatially resolved 2D-measurement to identify and quantify the gas emission from the structured soil would be needed, to better understand the influence of the soil sub-structures on the emission behavior. Thus we designed a spatially scanning laser absorption spectrometer setup to determine a 2D-gas concentration map in the soil-air boundary layer. The setup is designed to cover the surfaces in the range of square meters in a horizontal plane above the soil to be investigated. Existing field instruments for gas concentration or flux measurements are based on point-wise measurements, so structure identification is very tedious or even impossible. For this reason, we have developed a tomographic in-situ instrument based on TDLAS ("tunable diode laser absorption spectroscopy") that delivers absolute gas concentration distributions of areas with 0.8m $\times$ 0.8m size, without any need for reference measurements with a calibration gas. It is a simple and robust device based on a combination of scanning mirrors and reflecting foils, so that only very little optical alignment is necessary in the field. The measurement rate for a complete 2D field is presently up to 2.5 Hz. The measurement field size is currently limited only by laboratory conditions and could be extended easily to the range of several meters, as previous tests have confirmed[3]. A fast laser tuning rate of more than 5 kHz leads to high measurement path density, and overall more than 70% of a square shaped field area is covered. With this instrument, measurements of H_2O- and CH_4 – concentration distributions have taken place so far. We are going to discuss the instrument setup and the spectroscopic performance and present numerical studies concerning the tomographic reconstruction quality as well as first 2D reconstructions in the laboratory. The applicability to 2D CO_2 detection and the improvement of frame rate and reconstruction quality using faster laser tuning will be discussed.

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